

## Chapter 1: Introduction to the Chemistry of Life

### Matching

- A) phylogenetic
- B) negative
- C) H<sub>2</sub>O
- D)  $\Delta H^\circ$
- E)  $H - TS$
- F) halobacteria
- G) open
- H) entropy
- I) flux
- J) polymers
- K)  $\Delta G^\circ$
- L) thermophiles
- M) nitrogen
- N) positive

1. The most abundant molecule in the human body is \_\_\_\_\_.

Ans: C

Level of Difficulty: Easy

Section: 1.1.A

Learning objective: **The Origin of Life**

2. During chemical evolution, small organic molecules condense to form more complex molecules called \_\_\_\_\_.

Ans: J

Level of Difficulty: Easy

Section: 1.1.B

Learning objective: **The Origin of Life**

3. Evolutionary relationships can be visualized using a \_\_\_\_\_ tree.

Ans: A

Level of Difficulty: Easy

Section: 1.2.C

Learning objective: **Cellular Architecture**

4. The organisms most likely to be found in a brine environment would be \_\_\_\_\_.

Ans: F

Level of Difficulty: Easy

Section: 1.2.C

Learning objective: **Cellular Architecture**

5. The organisms most likely to be found in high temperature environments would be \_\_\_\_\_.

Ans: L

Level of Difficulty: Easy

Section: 1.2.C

Learning objective: **Cellular Architecture**

6. The term used to indicate the degree of randomness within a system is \_\_\_\_\_.

Ans: H

Level of Difficulty: Easy

Section: 1.3.B

Learning objective: **Thermodynamics**

7. Spontaneous processes are characterized by a change in Gibbs free energy that is \_\_\_\_\_.

Ans: B

Level of Difficulty: Easy

Section: 1.3.B

Learning objective: **Thermodynamics**

8. Gibbs free energy is defined as  $G =$  \_\_\_\_\_.

Ans: E

Level of Difficulty: Easy

Section: 1.3.C

Learning objective: **Thermodynamics**

9. The symbol for free energy under standard biochemical conditions is \_\_\_\_\_.

Ans: K

Level of Difficulty: Easy

Section: 1.3.C

Learning objective: **Thermodynamics**

10. Living creatures can be described thermodynamically as \_\_\_\_\_ systems.

Ans: G

Level of Difficulty: Easy

Section: 1.3.E

Learning objective: **Thermodynamics**

## Multiple Choice

11. What are the four most abundant elements in a human body?

- A) C, N, O, H
- B) C, N, O, P
- C) C, S, O, H
- D) C, Na, O, H
- E) none of the above

Ans: A

Level of Difficulty: Moderate

Section: 1.1.A

Learning objective: **The Origin of Life**

12. The atmosphere of prebiotic earth probably contained the following molecules:

- A)  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{N}_2$ ,  $\text{CH}_4$ , and  $\text{NH}_3$ .
- B)  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{C}_6\text{H}_{12}\text{O}_6$ , and  $\text{NH}_3$ .
- C)  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{C}_6\text{H}_{12}\text{O}_6$ , and  $\text{COO}^-\text{CH}_2\text{NH}_3^+$ .
- D)  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{COOHCH}_2\text{NH}_3$ , and  $\text{NH}_3$ .
- E) none of the above

Ans: A

Level of Difficulty: Easy

Section: 1.1.A

Learning objective: **The Origin of Life**

13. In 1953, Urey and Miller carried out an experiment in which they subjected a mixture of  $\text{H}_2\text{O}$ ,  $\text{CH}_4$ ,  $\text{NH}_3$ , and  $\text{H}_2$  to electrical discharges. Which of the following were among the products?

- A) proteins
- B) amino acids
- C) nucleic acids
- D) ribosomes
- E) all of the above

Ans: B

Level of Difficulty: Easy

Section: 1.1.A

Learning objective: **The Origin of Life**

14. Which of the following statements about hydrothermal vents is true?

- A) The vents have temperatures as high as  $800^\circ\text{C}$  and emit  $\text{H}_2\text{S}$  and metal sulfides.
- B) The vents have temperatures as high as  $600^\circ\text{C}$  and emit  $\text{H}_2\text{S}$  and metal nitrates.
- C) The vents have temperatures as high as  $400^\circ\text{C}$  and emit  $\text{H}_2\text{S}$  and metal sulfides.
- D) none of the above
- E) all of the above

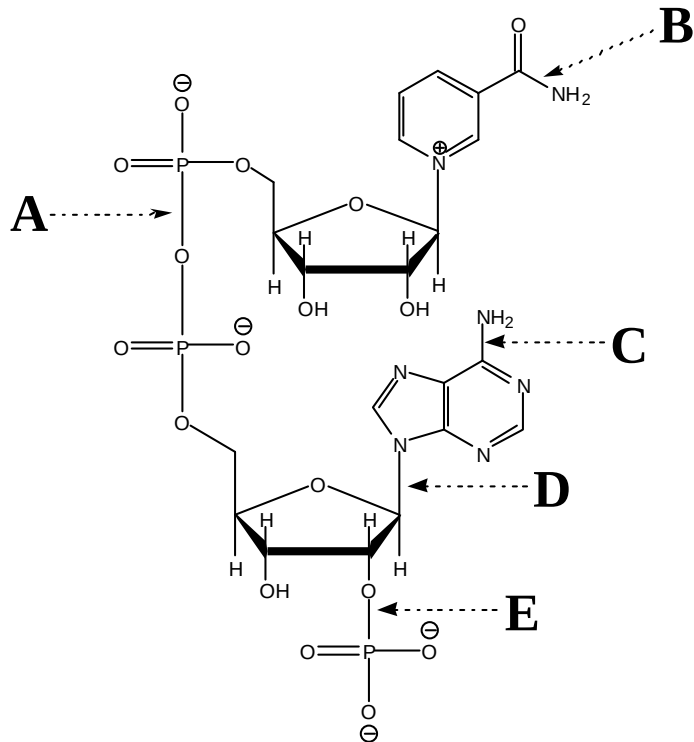
Ans: C

Level of Difficulty: Moderate

Section: 1.1.A

Learning objective: **The Origin of Life**

For questions 15-18, consider the structure of the coenzyme NADP



15. Which arrow points at a phosphate ester bond?
- A) A
  - B) B
  - C) C
  - D) D
  - E) E

Ans: E

Level of Difficulty: Easy

Section: 1.1.B

Learning objective: **The Origin of Life**

16. Which arrow points at an amide bond?

- A) A
- B) B
- C) C
- D) D
- E) E

Ans: B

Level of Difficulty: Easy

Section: 1.1.B

Learning objective: **The Origin of Life**

17. Which arrow points at an anhydride bond?

- A) A
- B) B
- C) C
- D) D
- E) E

Ans: A

Level of Difficulty: Moderate

Section: 1.1.B

Learning objective: **The Origin of Life**

18. Which arrow points at a glycosidic bond?

- A) A
- B) B
- C) C
- D) D
- E) E

Ans: D

Level of Difficulty: Moderate

Section: 1.1.B

Learning objective: **The Origin of Life**

19. Which of the following developed during the evolution of eukaryotic cells from prokaryotic cells?

- A) DNA
- B) the cell membrane
- C) nuclear membranes
- D) ribosomes
- E) proteins

Ans: C

Level of Difficulty: Easy

Section: 1.2.C

Learning objective: **Cellular Architecture**

20. Using phylogeny all living organisms can be divided into the following domains:

- A) bacteria, eukarya, and vertebrate
- B) archaea and eukarya
- C) bacteria, eukarya, and archaea
- D) eukarya and bacteria
- E) none of the above

Ans: C

Level of Difficulty: Moderate

Section: 1.2.C

Learning objective: **Cellular Architecture**

21. The theory of evolution includes which of the following principles?

- A) Evolution is not directed toward a specific goal.
- B) Evolution is ongoing, and is constrained by its past.
- C) Evolution requires some *sloppiness* for adaptation to changes.
- D) A and B
- E) A, B, and C

Ans: E

Level of Difficulty: Easy

Section: 1.2.D

Learning objective: **Cellular Architecture**

22. Which three cellular components are present in both prokaryotes and eukaryotes?
- A) ribosomes, chloroplasts, mitochondria
  - B) nucleus, ribosomes, RNA
  - C) RNA, DNA, ribosomes
  - D) endoplasmic reticulum, DNA, RNA
  - E) mitochondria, DNA, RNA

Ans: C

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

23. The bulk of aerobic metabolism in eukaryotic cells takes place in
- A) the endoplasmic reticulum.
  - B) the nucleus.
  - C) the mitochondria.
  - D) peroxisomes.
  - E) the Golgi apparatus.

Ans: C

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

24. Which cellular compartment or organelle is involved in the synthesis of proteins and lipids?
- A) endoplasmic reticulum
  - B) lysosomes
  - C) peroxisomes
  - D) vacuoles
  - E) all of the above

Ans: A

Level of Difficulty: Moderate

Section: 1.2.C

Learning objective: **Cellular Architecture**



25. Which of the following is a similarity between all prokaryotes and all eukaryotes?
- A) Both contain DNA in a nucleus.
  - B) Both contain some of the same membrane bound cell organelles (like mitochondria, Golgi complexes, etc).
  - C) Both have a cytoskeleton.
  - D) All of the above are similarities between prokaryotes and eukaryotes.
  - E) None of the above is a similarity between prokaryotes and eukaryotes.

Ans: E

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

26. Which of the following statements concerning prokaryotes is false?
- A) Prokaryotes are made up of two major groupings: the eubacteria and the archaea, which are as different from each other as from the eukaryotes.
  - B) Prokaryotes are generally much smaller than the eukaryotic cells.
  - C) Prokaryotes are one branch of the newer, more accurate phylogenetic tree made up of prokaryota, archaea and eukaryota.
  - D) Prokaryotes do not have organelles.
  - E) None of the above is false.

Ans: C

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

27. Which of the following statements about eukaryotes is not true?
- A) They contain organelles like mitochondria, chloroplasts, the endoplasmic reticulum and the nucleus.
  - B) They are usually 10 to 100 microns in diameter.
  - C) They can be either unicellular or multicellular.
  - D) They are also called archaea.
  - E) All of the above are true of eukaryotes.

Ans: D

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

28. Which of the following statements about the theories of (bio)chemical evolution is not true?

- A) During chemical evolution, simple organic molecules (monomers) condensed to form more complex molecules (polymers) which then began to replicate based upon complementarity.
- B) Margulis suggested that mitochondria and chloroplasts evolved from the symbiotic relationship between primordial prokaryotic and eukaryotic cells.
- C) The first cells were probably formed when self-replicating systems were enveloped in membranous vesicles.
- D) Oparin and Haldane demonstrated that by passing an electrical discharge through a vessel containing  $H_2O$ ,  $CO_2$ ,  $N_2$ ,  $CH_4$  and  $NH_3$  some basic biological building blocks (like simple amino acids) could have formed abiotically in the earth's early atmosphere.
- E) The RNA world hypothesis as proposed by Woese, Crick and Orgel states that RNA, instead of protein, was the first self replicating biochemical molecule that evolved because RNA could have stored genetic information and performed the catalytic roles necessary for primitive self-replication.

Ans: D

Level of Difficulty: Moderate

Section: 1.2.C

Learning objective: **Cellular Architecture**

29. Which of the following statement(s) is (are) not true?

- A) Margulis proposed the endosymbiotic theory to explain the evolution of mitochondria and chloroplasts.
- B) Woese proposed the “new” phylogenetic tree that divides living organisms into the 3 domains of bacteria, archaea and eukarya based upon genetic relationships rather than obvious morphological similarities.
- C) Urey and Miller conducted an experiment that involved sparking a mixture of  $NH_3$ ,  $CH_4$ ,  $H_2O$  and  $H_2$  gases to yield amino acids, some of the fundamental building blocks of life.
- D) All of the above are false.
- E) All of the above are true.

Ans: E

Level of Difficulty: Easy

Section: 1.2.C

Learning objective: **Cellular Architecture**

30. Halophiles and thermophiles are
- A) early versions of eukaryotic cells.
  - B) highly evolved organisms that thrive in their specific environments.
  - C) relatively inefficient and unevolved organisms.
  - D) more complex than eukaryotes.
  - E) extremely slow growing.

Ans: B

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

31. Which of the statements about viruses is not true?
- A) Viruses are much simpler than cells.
  - B) Viruses are the simplest living organisms.
  - C) Viruses lack the necessary metabolic apparatus to reproduce.
  - D) Viruses are dependent on host cells.
  - E) All the statements are true.

Ans: B

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

32. Lynn Margulis' Theory of Endosymbiosis is an explanation for the origin of
- A) the endoplasmic reticulum.
  - B) the nucleus.
  - C) the mitochondria.
  - D) peroxisomes.
  - E) the Golgi apparatus.

Ans: C

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

33. Phylogeny is
- A) the science of biological classification based on gross morphology.
  - B) the science of biological classification based on the evolutionary relationships between organisms.
  - C) the science of biological classification based on reproductive strategies.
  - D) the branch of science that studies phyllo pods.
  - E) none of the above

Ans: B

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

34. Taxonomy is
- A) the science of biological classification based on gross morphology.
  - B) the science of biological classification based on the evolutionary relationships between organisms.
  - C) the science of biological classification based on reproductive strategies.
  - D) the branch of science that studies taxidermy.
  - E) none of the above

Ans: A

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

35. Which group of organisms is not prokaryotic?
- A) Fungi
  - B) Archaea
  - C) Purple bacteria
  - D) Cyanobacteria
  - E) Methanococcus

Ans: A

Level of Difficulty: Easy

Section: 1.2.B

Learning objective: **Cellular Architecture**

36. The term *molecular weight* is a term used by biochemists that refers to
- A) the density of a particle.
  - B) a dimensionless quantity that is defined as the ratio of the mass of the particle to 1/12 the mass of a  $^{12}\text{C}$  atom.
  - C) Daltons divided by the mass of a hydrogen atom.
  - D) all of the above
  - E) none of the above

Ans: B

Level of Difficulty: Moderate

Section: 1.3.A

Learning objective: **Thermodynamics**

37. The second law of thermodynamics states:
- A) that spontaneous processes are characterized by the overall conversion of order to disorder.
  - B) that spontaneous processes are characterized by the conversion of work to force.
  - C) that nonspontaneous processes are characterized by the conversion of order to disorder.
  - D) that spontaneous processes are characterized by the conversion heat to pressure.
  - E) none of the above

Ans: A

Level of Difficulty: Easy

Section: 1.3.B

Learning objective: **Thermodynamics**

38. Change in enthalpy ( $\Delta H$ ) is best defined as
- A) the sum of heat absorbed and work done.
  - B) the heat transferred at constant pressure.
  - C) the pressure change at constant temperature.
  - D) the measure of disorder in a system.
  - E) none of the above

Ans: B

Level of Difficulty: Easy

Section: 1.3.B

Learning objective: **Thermodynamics**

39. If gas molecules in an enclosed chamber are allowed to enter a second chamber, the resulting redistribution of gas molecules represents an increase in

- A) enthalpy.
- B) entropy.
- C) force.
- D) chemical potential.
- E) all of the above

Ans: B

Level of Difficulty: Easy

Section: 1.3.B

Learning objective: **Thermodynamics**

40. Consider the reaction  $A + B \leftrightarrow C + D$ . After reaching equilibrium at  $25^\circ\text{C}$ , the following concentrations of reactants and products were measured:  $[A] = 10 \mu\text{M}$ ,  $[B] = 15 \mu\text{M}$ ,  $[C] = 10 \mu\text{M}$ ,  $[D] = 10 \mu\text{M}$ . Calculate  $\Delta G^\circ$  for this reaction.

- A) 1000 J/mol
- B) 10 kJ/mol
- C) 1 J/mol
- D) insufficient data to determine answer
- E) none of the above

Ans: A

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: **Thermodynamics**

41. A reaction with a \_\_\_\_\_  $\Delta H$  and a \_\_\_\_\_  $\Delta S$ , will never be spontaneous.

- A) positive, positive
- B) positive, negative
- C) negative, positive
- D) negative, negative
- E) none of the above

Ans: B

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: **Thermodynamics**

42. An endergonic reaction with a \_\_\_\_\_  $\Delta H$  and a \_\_\_\_\_  $\Delta S$  can be changed into an exergonic reaction by decreasing the temperature.

- A) positive, positive
- B) positive, negative
- C) negative, positive
- D) negative, negative

Ans: D

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: **Thermodynamics**

43. The  $\Delta G^\circ$  for the conversion of glucose 6-phosphate (G6P) to fructose 6-phosphate (F6P) is +1.7 kJ/mole. In a particular human cell the concentration G6P is 8.0  $\mu\text{M}$  and the concentration F6P is 1.0  $\mu\text{M}$ . Calculate the  $\Delta G$  of the reaction as it occurs in this cell at 37°C?

- A) -37 kJ/mol
- B) -3.7 kJ/mol
- C) 0 kJ/mol
- D) +7.1 kJ/mol
- E) -0.6 kJ/mol

Ans: B

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: Thermodynamics

44. For a reaction with  $\Delta H = 23 \text{ kJ/mol}$  and  $\Delta S = 22 \text{ J/K}\cdot\text{mol}$ , at 2°C, the reaction is:

- A) spontaneous
- B) nonspontaneous
- C) at equilibrium
- D) impossible to determine reactivity
- E) none of the above

Ans: B

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: **Thermodynamics**

45. Calculate the  $\Delta G$  for a reaction with  $\Delta H = 20. \text{ kJ/mol}$  and  $\Delta S = 20. \text{ J/K}\cdot\text{mol}$ , that is carried out at  $27^\circ\text{C}$ .

- A) 14 J/mol
- B) 140 J/mol
- C) 1400 J/mol
- D) 14,000 J/mol
- E) none of the above

Ans: D

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: **Thermodynamics**

46. A spontaneous process

- A) occurs without the addition of free energy.
- B) has a  $\Delta G < 0$ .
- C) is exergonic.
- D) is all of the above
- E) is none of the above

Ans: D

Level of Difficulty: Easy

Section: 1.3.C

Learning objective: **Thermodynamics**

47. An increase in disorder in the system

- A) is required for a process to be spontaneous.
- B) results in a decrease in entropy.
- C) is characteristic of a system increasing in enthalpy.
- D) results in the factor  $T\Delta S$  being positive .
- E) is found in every exergonic process.

Ans: D

Level of Difficulty: Moderate

Section: 1.3.B

Learning objective: **Thermodynamics**



48. Living organisms
- A) are closed systems.
  - B) maintain a steady state.
  - C) exist outside the laws of thermodynamics.
  - D) are all of the above
  - E) are none of the above

Ans: B

Level of Difficulty: Easy

Section: 1.3.E

Learning objective: **Thermodynamics**

49. Enzymes accelerate biochemical reactions by
- A) decreasing the  $\Delta G$  for the reactions.
  - B) increasing the  $\Delta G$  for the reactions.
  - C) establishing a 'closed system' for each reaction.
  - D) promoting reaction pathways associated with a positive  $\Delta G$ .
  - E) providing a more favorable pathway for the reactions.

Ans: E

Level of Difficulty: Moderate

Section: 1.3.E

Learning objective: **Thermodynamics**

50. A van't Hoff plot
- A) plots  $\ln K_{eq}$  versus T
  - B) plots  $\Delta K$  versus  $-T\Delta S$ .
  - C) plots  $K_{eq}$  versus  $1/T$ .
  - D) is a good method to determine  $\Delta H^\circ$  and  $\Delta S^\circ$ .
  - E) determines  $K_{eq}$  by plotting  $\Delta H^\circ$  versus  $1/T$ .

Ans: D

Level of Difficulty: Moderate

Section: 1.3.D

Learning objective: **Thermodynamics**

51  $K_{eq}$  can be determined from the change in standard free energy using the equation

- A)  $K_{eq} = e^{-\Delta G^\circ/RT}$
- B)  $K_{eq} = \ln e^{-\Delta G^\circ/T\Delta S}$
- C)  $K_{eq} = e^{-\Delta H/RT}$
- D)  $K_{eq} = e^{-\Delta G^\circ/T\Delta S}$
- E)  $K_{eq} = \log e^{-\Delta G^\circ/RT}$

Ans: A

Level of Difficulty: Easy

Section: 1.3.D

Learning objective: **Thermodynamics**

52. Living organisms are classified thermodynamically as:

- A) open systems.
- B) closed systems.
- C) isolated systems.
- D) thermally isolated.
- E) none of the above

Ans: A

Level of Difficulty: Easy

Section: 1.3.D

Learning objective: **Thermodynamics**

## Short answer

53. Carbohydrates, proteins, nucleotides, and nucleic acids are important groups of molecules found in living organisms. Which 6 elements do living organisms need to build these molecules?

Ans: C, H, O, N, S, P

Level of Difficulty: Moderate

Section 1.1.A

Learning objective: **The Origin of Life**

54. Explain in one or two sentences why scientists believe that all living organisms are related (that they have all evolved from a common ancestor)?

Ans: Biochemically, all living organisms are very similar.

Level of Difficulty: Moderate

Section 1.2.C

Learning objective: **Cellular Architecture**

55. Consider a reaction in which  $\Delta H = -20. \text{ kJ/mol}$  and  $\Delta S = 10. \text{ J/mol} \cdot \text{ K}$ .

- Calculate the  $\Delta G$  for this reaction at  $25^\circ\text{C}$ .
- Is the reaction spontaneous (explain your answer)?

Ans: a.  $\Delta G = \Delta H - T\Delta S \Rightarrow \Delta G = -20,000 \text{ J/mol} - (298 \times 10 \text{ J/mol}) = -23,000 \text{ J/mol}$

b. The reaction is spontaneous because the  $\Delta G$  is negative.

Level of Difficulty: Moderate

Section 1.3.C

Learning objective: **Thermodynamics**

56. Consider the isomerization reaction  $R \rightleftharpoons P$ , in which R is converted to P. The  $\Delta G^\circ$  for this reaction is  $-10. \text{ kJ/mol}$ . Calculate the  $[P]/[R]$  at equilibrium at  $25^\circ\text{C}$ .

At equilibrium  $[P]/[R] = K_{\text{eq}} = e^{-\Delta G^\circ/RT} \Rightarrow$

$$[P]/[R] = e^{-(-10000 \text{ J/mol})/8.3145 \cdot \text{x} 298 \text{ J/mol}} = e^{10000/8.3145 \cdot \text{x} 298} = 57$$

Level of Difficulty: Moderate

Section 1.3.D

Learning objective: **Thermodynamics**

57. Phosphoglucosyltransferase catalyses the reaction in which a phosphate group is transferred from the 1 carbon of glucose to the 6 carbon of glucose ( $\text{G1P} \rightleftharpoons \text{G6P}$ ). A student at SDSU incubates a  $0.2 \text{ M}$  solution of glucose-1-phosphate overnight with a small amount of the enzyme. At equilibrium the concentration of glucose 1-phosphate is  $9.0 \times 10^{-3} \text{ M}$  and the concentration of glucose 6-phosphate is  $19.1 \times 10^{-2} \text{ M}$ .

Calculate the equilibrium constant ( $K_{\text{eq}}$ ) and the standard state free energy ( $\Delta G^\circ$ ) for this reaction at  $25^\circ\text{C}$ .

Ans: The equilibrium constant  $K_{\text{eq}} = [\text{G6P}]_{\text{eq}}/[\text{G1P}]_{\text{eq}} = 19.1 \times 10^{-2} \text{ M}/9.0 \times 10^{-3} \text{ M} = 21.2$ .  
 $\Delta G^\circ = -RT \ln K_{\text{eq}} = -8.3145 \times 298 \text{ J/mol} \times \ln 21.2 = -7,600 \text{ J/mol}$ .

Level of Difficulty: Difficult

Section 1.3.D

Learning objective: **Thermodynamics**

58. The reaction  $\text{pyruvate} + \text{ATP} \rightleftharpoons \text{PEP} + \text{ADP}$  is catalyzed by the enzyme pyruvate kinase. The  $\Delta G^{\circ}$  for this reaction is 31.4 kJ/mol. Use this information to answer the following questions.

- Does this reaction move forward (from left to right) or backward under standard state conditions? Explain your answer in one sentence.
- Calculate the  $K_{\text{eq}}$  for this reaction at 25°C.
- After the reaction has reached equilibrium at 25°C  $[\text{ATP}] = 5 \text{ mM}$ ,  $[\text{ADP}] = 0.5 \text{ mM}$ ,  $[\text{pyruvate}] = 0.2 \text{ mM}$ . Calculate the concentration PEP.

Ans: a. The reaction goes backward (from right to left) because  $\Delta G^{\circ}$  for the forward reaction is positive.

b.  $K_{\text{eq}} = e^{-\Delta G^{\circ}/RT} = e^{-31400/8.3145 \times 298} = 3.13 \times 10^{-6}$

c.  $K_{\text{eq}} = [\text{ADP}]_{\text{eq}} \times [\text{PEP}]_{\text{eq}} / [\text{ATP}]_{\text{eq}} \times [\text{Pyruvate}]_{\text{eq}} \Rightarrow$

$3.1 \times 10^{-6} = 0.5 \text{ mM} \times [\text{PEP}]_{\text{eq}} / 0.2 \text{ mM} \times 5 \text{ mM} \Rightarrow$

$[\text{PEP}]_{\text{eq}} = (3.1 \times 10^{-6} \times 0.2 \text{ mM} \times 5 \text{ mM}) / 0.5 \text{ mM} = 6.2 \times 10^{-6} \text{ mM} (6.2 \times 10^{-9} \text{ M})$

Level of Difficulty: Difficult

Section 1.3.D

Learning objective: **Thermodynamics**